Equipment and technologies for improving the processes of transportation of drilled rock

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Abstract. In this paper, an analysis of existing equipment for cleaning the bottom of the well from sludge during rotary drilling is carried out to find ways to improve the processes of transporting drilled rock. The article is devoted to the issue of improving the processes of transportation of drilled rock in the process of drilling oil and gas wells. Complications and accidents during the wiring of directional and horizontal wells are presented, the cause of which is insufficient well cleaning. The relevance of the task related to the development of highly efficient equipment and technologies for cleaning the bottom of the well from drilled rock is substantiated. An over-drilling device has been developed for cleaning vertical, inclined and horizontal wells from drilled rock. A schematic diagram of the work of the developed technical solution to improve the efficiency of cleaning the face and trunk of vertical, inclined and horizontal wells from drilled rock when drilling with a roller bit is presented.

1 Introduction

Russia's energy strategy provides for an annual increase in oil production. The increase in oil and gas production is inextricably linked with an increase in the technical and economic indicators of the well drilling process. The construction time of wells can be reduced by increasing drilling speeds by using new types of rock-crushing tools, new types of flushing fluids, circulation system equipment: drilling pumps, equipment for the preparation and purification of flushing fluid, as well as by reasonably improving the operation of equipment. An essential reserve in improving the efficiency of drilling operations is the improvement of drilling techniques and technology based on the introduction of effective equipment for cleaning the bottom of wells from sludge. The degree of perfection of well flushing and the equipment for its implementation significantly affects the successful, trouble-free wiring of wells. The quality of cleaning the bottom of the well from sludge affects the mechanical drilling speed, the quality of the borehole, the penetration and durability of the bit, turbobur, and the layout elements of the drilling tool [7].

The faces of oil and gas wells during drilling, as a rule, are clogged with large drilling sludge, which leads to a deterioration in the process of rock destruction and a decrease in

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the performance of the bits [1]. With increasing drilling depth, an increasing amount of sediment remains at the bottom, consisting mainly of large-sized sludge [3]. Sludge removal is complicated when drilling deep vertical, inclined and horizontal wells, as well as when drilling shallow wells - when the circulation of the flushing liquid does not create sufficient upward flow to remove the sludge. The most urgent problem is the cleaning of the horizontal borehole from the drilled rock. At the moment, horizontal drilling during the construction and reconstruction of wells is the most promising way to develop oil and gas reserves [2, 5]. The development of oil and gas fields using horizontal wells is a priority in the oil and gas industry for the involvement of hard-to-recover oil reserves in industrial development (low-permeability and heterogeneous formations and reservoirs confined to water-oil and gas-oil zones, oil fringes of oil and gas deposits; deposits with high-viscosity oil, dead-end, peripheral and stagnant zones, with lenticular interlayers of various configurations, etc.) [4].

Insufficient cleaning of drilled rock is the main cause of complications and accidents during the wiring of horizontal wells, more than 80% of seizures occur due to narrowing of the borehole section during sludge subsidence. Due to complications and accidents caused by inefficient cleaning of wells with a large deflection angle, additional costs can reach up to 60% of the total cost of well construction [6]. Poor cleaning of wells from sludge leads to complications such as a decrease in the load on the bit, an unregulated change in the trajectory of the trunk, difficulty orienting the drilling tool, a change in the nature of the downhole arrangements, absorption of flushing fluid, hydrodynamic tack [9].

The removal of sludge from the bottom and trunk of horizontal wells in comparison with vertical ones is difficult due to the radial orientation of gravitational forces acting on sludge particles and the eccentric location of the drill string in the wellbore.

Due to the complication of the conditions for the removal of sludge particles by flushing liquid when drilling directional and horizontal wells, the effect of flushing increases, and the use of most technological and design solutions related to the transportation of drilled rock to the daytime surface is ineffective.

2 Methods and Materials

The analysis of existing techniques and technologies for cleaning the bottom of the well from drilled rock during drilling in a rotational manner to find the direction of improving the cleaning of the bottom-hole zone of the well is carried out.

F.A. Agzamov, T.O. Akbulatov, K. A. H. Alvan, T. E. Becker, A. I. Bulatov, M.S. Gabdrakhimov, N.A. Gukasov, B.I. Esman, G.P. Zozulya, V.I. made a great contribution to solving theoretical and practical issues of sludge removal from wells with large zenith angles and horizontal ones. Isaev, A.G. Kalinin, V.V. Kretsul, V.I. Krylov, E.G. Leonov, A.H. Mirzajanzade, J. J. Ozara, S. Okrazhi, G.A. Panfilov, A.N. Popov, V.I. Ryabchenko, B. Z. Sultanov, V.A. Fisher, R. I. Shishchenko, etc.

There are various techniques and technologies to improve the quality of cleaning the borehole from sludge: improving the qualitative composition of the drilling mud; increasing the flow rate of the flushing liquid; backwash; devices with separation of the flow of the flushing liquid; flushing the borehole with periodic lifting of the drill string by several candles and re-penetration of the passed interval; introduction of devices with better hydrodynamic properties.

To increase the efficiency of cleaning the face and the borehole from the drilled rock, various devices built into the chisel are used: ball, balancing, acoustic vibrators. Improving the quality of cleaning horizontal shafts can be carried out by creating radial vibrations of the drill string [8]. The use of vibration technologies also reduces the amount of friction forces of the drill string against the walls of the well [2]. The disadvantage of using

vibrators in the layout of a drilling tool is that in an extended horizontal section of the borehole, it will be necessary to install two or more oscillation generators in the drill pipe column and comply with the conditions of their self-synchronization in order to increase the efficiency of using the hydraulic power of drilling pumps consumed by generators.

Various overhanging devices are used to improve the cleaning of the face: a translator equipped with a screw; drill pipes with a helical spiral fin; jet pumps of various designs. These devices improve the cleaning of the face from sludge to a certain extent, but do not ensure the removal of large, solid sludge particles, allow for repeated crushing of the sludge, the formation of sludge dunes during horizontal drilling.

There are special chisels for intensifying the cleaning of the borehole from sludge [13]. Perfect flushing of the borehole and the bit means the immediate and complete removal of the sludge formed as a result of the interaction of the teeth of the bit with the rock. The rock fragments created by one tooth must be removed before interacting with the rock of the next tooth in such a way that all the rock-destroying elements of the chisel are constantly in contact only with the rock. In this case, with a certain amount of mechanical energy spent on rock breaking, the penetration rate will be maximum; otherwise, part of this energy will be spent uselessly on the destruction of rock fragments that have already formed, but have not been removed from the face, in particular due to the pressure of the drilling mud column and the well. In permeable rocks, under the influence of this pressure, a colmatation crust is formed almost instantly at the bottom, consisting of solid particles of drilling mud or drilled rock, which reduces the depth of penetration of teeth into the rock. This phenomenon is known as the formation of an "oil seal" (or slurry cushion) at the bottom [11].

The parameters determining the quality of face flushing — the average jet velocity, power, impact force and dynamic pressure of the jets, the speed of streams parallel to the face — have maximum values at a small distance between the nozzle and the face [12].

One of the ways to improve the characteristics of bits with a peripheral flushing system is to bring the nozzles closer to the bottom of the well [14-16]. However, the extension pipes in which the nozzles are installed are subject to excessive wear and even destruction.

Due to the complication of the conditions for the removal of sludge particles by flushing liquid when drilling directional and horizontal wells, the effect of flushing increases, and the use of most technological and design solutions related to the transportation of drilled rock to the daytime surface is ineffective.

3 Results and Discussion

During horizontal drilling, all the particles of the drilled rock tend to sink to the bottom wall of the well. Two sludge transportation mechanisms are possible:

- At a sufficiently high flow velocity, turbulent pulsations (vortices) pick up sludge particles and transfer them to the region of high flow velocities. As the vortex fades, the particles begin to settle until they are picked up by the next vortex. In this way, the transfer of particles in a suspended state is carried out.
- If the average value of the transverse velocity pulsations is less than the sedimentation rate of solid particles, then the solid phase will begin to settle on the lower wall of the well, forming sediments. The settled particles can move along the surface of the sediment if the force of action on the particle from the liquid side is greater than the forces of resistance to the movement of the particle. Such a mechanism of particle movement is called displacement in the entrained state [7].

To prevent sedimentation of sludge and sediment formation, it is necessary that the particles of the drilled rock be in a suspended state, and not in a dragged state. However, an increase in the supply and an increase in the density of the drilling fluid leads to colmation

of the walls of the well. According to the literature, it is known that it is possible to transport particles of drilled rock in a suspended state with a size of no more than 1-2 mm [10].

To increase the efficiency of cleaning wells from sludge, a superdolling device has been developed, passing through which large particles of sludge are crushed to a size of 2 mm or less. The drum (mesh) is mounted on the turbobur shaft and connected to the rotating shaft using springs. The rotating shaft of the turbobur and the drum connected by springs form an oscillatory system. When the turbobur shaft rotates, torsional vibrations of the drum are created due to the presence of springs, which ensures grinding and sieving of the sludge.

The device is installed during rotary drilling (rotary method, downhole motors) above the bit. Figure 1 shows a schematic diagram of the operation of the above-ground slurry shredder during turbine drilling.

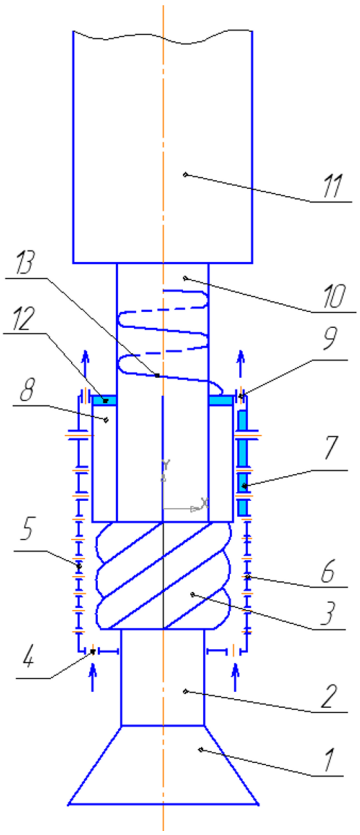

Fig. 1. Schematic diagram of the operation of a superdolled slurry shredder during turbine drilling.

The main parts of the device are the housing 2, which is equipped with a screw 3 and a rotor 8, and a drum 5. The screw and rotor are installed inside the drum, which has input and output channels 4, 9, holes 6, and a bump 7. In the upper part, the drum is equipped with a ribbed surface 12, which is mated to the end of the rotor. The device is equipped with an auger that sucks up the sludge and directs it to the rotor, which in turn throws the sludge onto the drum chipper 7. In this case, the sludge is crushed, small particles of sludge are sifted through the drum, large particles are repeatedly crushed by the end of the rotor. The design of a springless overhead device (Figure 2) has also been developed.

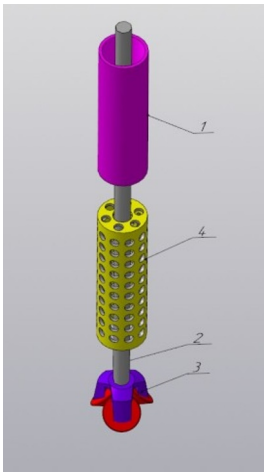

Fig. 2. Schematic diagram of the drive of the drum-grid of the overhead device.

Conclusion

A design has been developed for a head-mounted device that provides crushing, sieving and removal of sludge from the bottom when drilling vertical, inclined and horizontal wells, the liquid with the slurry is directed by the auger in the axial and radial directions, while the sludge is partially crushed due to impacts, small particles are sieved through a grid (mesh holes 2-3 mm), large particles enter the rotor they are thrown radially onto the reflector, further crushing of the sludge occurs. The final grinding occurs when large particles enter the channels and are crushed by the end of the rotor. The solution is cleaned by torsional vibrations of the drum (grid), which occur under the action of the inertia force of the drum, the liquid thrown by the rotor onto the eccentric reflector and the forces of the springs.

The task associated with the development of highly efficient equipment for cleaning the bottom of the well from sludge is urgent. The design of an over-drilling device has been developed that provides crushing, sieving and removal of sludge from the bottom during drilling of vertical, inclined and horizontal wells. The use of the developed design of a superdolled slurry shredder will increase the mechanical drilling speed compared to the conventional method, and will also help reduce complications and accidents caused by inefficient cleaning of shafts with a large deflection angle.

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